9.0 Measurement Management Use Cases

9.1 Overview of Measurement Management Use Cases

The use cases for Measurement Management (MM) are intended to manage survey measurement and other geometric data in an automated environment. The inputs into the Measurement Management system are the following:

- **Measured bearings and distances** of lines from the Survey Management system, other digital sources, paper records and data attributes,
- **Measured geographic coordinates** of corners, as well as attributes,
- **Terrain-based boundaries** extracted from traditional map coverages, and
- **Rules of construction** for further division of land, as interpreted from legal records. Examples are offsets and PLSS section subdivision.

The purpose of Measurement Management is twofold. One purpose is to combine the individual components of measurement data from a variety of sources and reliabilities (pre-adjusted measurement network) into a seamless and coherent network (adjusted measurement network). The second purpose is to further divide the network to its needed detail based on legal descriptions to form all the spatial features needed to display the known legal descriptions (legal description fabric).

The general steps (and use cases) included in Measurement Management are:

- Assemble all measured feature components for the adjustment area, including error estimates and data source descriptions. (System Utilities such as **Input** and **Import Data**; Use cases: ***MM-01 Construct Measured Feature, MM-03 Edit Measurement Data)***
- Perform least square adjustment/analysis, which includes automatic transforms of data to common units and projections. (Use case: ***MM-02 Adjust and Analyze Measurement Network***.)
- Inspect analysis results for anomalies that may indicate data entry blunders. Fix blunders. (Use cases: ***MM-03 Edit Measurement Data***.)
- Option: Inspect results of analysis on blunder-free data for clues to refine error estimates. (Use cases: ***MM-03 Edit Measurement Data***)
- Apply stored rules and further divide the network into pieces as interpreted from legal records. (Use case: ***SM-05 Perform COGO and Layout***.)
- Copy the results into the legal description fabric, overwriting what existed in the adjustment area.

Creating measurement networks with Measurement Management provides the foundation for the legal description and parcel fabric tiers. Integrated maintenance of cadastral data is made much more efficient when geometry can be shared. The measurement management functionality should assist in the interpretation of (1) the reliability of each point position and (2) where data editing is needed. Based on such an interpretation, new data can be added to the pool of measurement data and elements that no longer aid the optimal solution can be removed. Any area can be selected and adjusted, usually based on what point positions will be enhanced by the new data being added. New data, once attributed and verified as *blunder*-free, can be integrated into a seamless network.

9.2 Measurement Management Use Case Analysis

The remainder of this section presents the individual Measurement Management use cases. In the NILS 'Field-to-Fabric' concept, Measurement Management use cases are used to build measurement networks as the geometric sources for fabrics.

Please note that Measurement Management as a process would have access to the system functionality provided to support other use cases. Therefore use cases such as ***SM-05 Perform COGO and Layout***, and Make Formatted Output (a system requirement) are utilized in the measurement management process, but are not included in this section.

Table 9.1 lists the Measurement Management use cases. Figure 9.1 shows the relationship of these use cases to the other NILS use cases.

Table 9.1. Measurement Management Use Cases

Use Case	Section	Description
MM-01 Construct Measured Feature	9.3	*Measured Features* are constructed from component elements in a *measurement network* by applying construction and *computation* methods. *Measured features* have topological associations to their component elements (i.e. component features and/or *survey points*.) This use case may be used in conjunction with building a *measurement network*, a *legal description fabric*, or a *parcel fabric*.
MM-02 Adjust and Analyze Measurement Network	9.4	Perform an iterative *parametric least squares adjustment* on a *measurement network* to analyze and adjust coordinate values for *points*. Generate statistics on *measurement* and coordinate reliability. May be used in resolving the cartographic and/or coordinate representation (relationship) of non-survey *features* (map control, *legal descriptions*, digitized, scanned/vectorized) relative to surveyed *features*. May be used to resolve the representation of non-surveyed *features* without reference to surveyed *features*. NOTE: A *measurement network* may be composed of *legal descriptions* as well as *measurements*.
MM-03 Edit Measurement Data	9.5	Manual entry/edit of *measurement data* values. Includes types of *anomaly detection* and *anomaly correction* as part of edit validation.

Figure 9.1. Business Process Analysis—Measurement Management Use Cases

SYSTEM

General Requirements
- Manage Data Transformation
- Make Formatted Output
- Compare/Contrast Data
- Reconstruct Historical Version of Data
- Administer Data Access Rights
- Audit Workflow Process

SURVEY MANAGEMENT

Research
- SM-01SurveyResearch

Capture Survey Readings and Observations
- SM-02 Pre-Field Survey Setup
- SM-03 In-Field Survey Setup
- SM-04 Collect Field Data Observations
- SM-05 Perform COGO and Layout

MEASUREMENT MANAGEMENT

Analyze Survey Data and Construct Measurements
- MM-01Construct Measured Feature
- MM-02 Adjust Analyze Measurement Network
- MM-03 Edit Measurement Data

PARCEL MANAGEMENT

Identify and Verify Legal Descriptions
- PM-01 Verify Parcel

Add, Create, Construct Legal Descriptions
- PM-02 Construct Legal Description

Manage Legal Description Fabric (resolve gaps and overlaps)
- PM-03 Edit Legal Description Fabric
- PM-04 Re-Adjust Fabric

Construct Parcels from Legal Description Components
- PM-05 Edit Parcel Fabric
- PM-06 Edit Parcel Annotation

GEOCOMMUNICATOR

GeoCommunicate
- GC-01 Conduct Search
- GC-02 Browse Search Results
- GC-03 Submit Event
- GC-06 Submit Data
- GC-10 Post Comment

Manage Communications
- GC-04 Manage Event Notification Process
- GC-05 Manage Provider Account
- GC-07 Manage Subscriber Account
- GC-08 Manage Data Process
- GC-09 Manage Accounts
- GC-11 Manage Forums

9.3 MM-01 Construct Measured Feature

9.3.1 MM-01 Construct Measured Feature Analysis

Context

The fundamental concept behind measured features is the establishment of topological associations that can transform measurement-based features into super-features that are constructed from, and may adjust with, their underlying measurements. A feature class in a measurement data set can be a mixed collection of (ordinary) features and measured features—this provides the migration path for current GIS actors to evolve their cadastral feature fabrics into a measurement-based fabric over time.

Concepts

Measured Feature. A feature constructed from component elements in a measurement network by applying construction and computation methods. Measured features have topological association to component features and/or measurements.

Measurement Network. A set of topologically related measurements (coordinate points and lines) and constructions (area-based features, non-surveyed features). May be in various states of connectivity and adjustment. Types:

> ***Pre-Adjusted Measurement Network.*** Multiple coordinate values exist for some points, so lines which should be connected may not be (due to measurement errors).
>
> ***Adjusted Measurement Network.*** All *over-determined points* have unique coordinates.
>
> ***Legal Description Fabric.*** An *adjusted measurement network* to which constructions (terrain feature boundaries, non-survey data) have been added. All polygons representing legally-described areas have been formed from the measurement network and other boundaries to support the parcel fabric.
>
> ***Parcel Fabric.*** A feature class related that has been modified to represent parcel configuration for a specific business purpose (e.g., ownership parcels, tax parcels, historic parcels). Parcel features may be associated with component features in the Legal Description Fabric.

Survey Point. A point feature that has XYZ coordinate values. Any point in a *measurement network*. Each s*urvey point* has a list of coordinate values or a c*oordinate set*.

Key Features and Functionality

This set of operations is basically a set tools that apply the necessary computations to construct various types of measured features.

Example Measured Feature Types. *Legal Description* (section, government lot, city lot, aliquot part, etc.), *True Line, Boundary, Representative Corner* (multiple; porcupine; theoretical), *Corner, Parcel, Administrative Area*, etc. May include physical objects such as buildings and other structures.

Example Computations. Section subdivision, *offset line, defining measurement, proportion, intersection* (distance-distance). Note: methods may be geodetic/non-geodetic.

Application Integration

In the course of constructing measured features, the system may use COGO and Layout functions (see ***SM-05 Perform COGO and Layout***). The construction of measured features may often occur within the context of editing measurement data or fabrics. An example is the construction of a legal description and the operations necessary to edit the legal description fabric.

Development Implications

In the NILS system model, field surveys produce observations that are built into measurements. Measurements are associated, survey-based features within a measurement network. The elements of a measurement network are mass-adjusted using a *parametric least-squares analysis* to yield most probable coordinate values for all points.

Before a measured feature can be constructed, some underlying survey-based features must exist within a measurement network. The minimal unit required is a survey point. A survey point can become a measured corner. A set of two survey points defined as measured corners can be used to construct a measured line. A survey point combined with the necessary parameters can be used to construct a measured curve. Measured lines and curves can be joined at measured corners to define a measured area. Measured areas can be associated through rules of aggregation and division to define a feature fabric (legal description, parcel).

9.3.2 MM-01 Construct Measured Feature Overview

Use Case	MM-01 Construct Measured Feature
Description	*Measured Features* are constructed from component elements in a *measurement network* by applying construction and *computation* methods. *Measured features* have topological associations to their component elements (i.e. component *features* and/or *survey points*.) This use case may be used in conjunction with building a *measurement network*, a *legal description fabric*, or a *parcel fabric*.
Actors	Surveyor, Supervisor, Parcel Editor
Pre-Condition	Component *survey points* and *measured features* are available. Actor wants to construct a new *Measured Feature* from supporting data.
Post-Condition	A *measured feature* is constructed and attributed appropriately.
Cross-Reference	***SM-05 Perform COGO and Layout; MM-03 Edit Measurement Data; PM-02 Construct Legal Description***

9.3.3 MM-01 Construct Measured Feature Primary Scenario

Actor Action	System Response
1. This use case begins when a actor launches the ***MM-01 Construct Measured Feature*** process.	2. Display current *measurement data set* (may include *measured features*, *survey points* and reference features). Provide tools for selection and construction. Note: measurement-based elements in a *measurement data set* have *computation* methods that are automatically applied to properly construct and display the *measurement data set*. [no data set] Establish current measurement data set
3. Select spatial extent in which to perform *Measured Features* construction.	4. Update display (includes symbology to indicate both type and status of measurement data set elements). Display choices for *computation* methods to support construction of *Measured Features*.
5. Select type of *Measured Features* to construct.	6. Process through construction steps, prompt for actor input as needed.
7. Select *survey points* and/or existing *Measured Features* that define the new *Measured Feature*. Input appropriate attribute values for the new *Measured Feature*.	8. Apply computation methods associated with construction rule and construct new *Measured Feature* with inherent attribute values (e.g., curve construction parameters, boundary type, object links, ID, metadata, etc.). Display new *Measured Feature*. Choice of Save, Revise, Next Feature, Quit.

Actor Action	System Response
9. Select from choices	10. Perform chosen operation. [save] Save to measurement data set. [revise] Return to #7. [next] Return to #5. [quit] Exit.
NOTE: No secondary scenarios	

9.4 MM-02 Adjust and Analyze Measurement Network

9.4.1 MM-02 Adjust and Analyze Measurement Network Analysis

Context

Adjustment and Analysis together are the core of Measurement Management, the second phase in the Field-to-Fabric process (i.e., surveying to measurement management to parcel management).

It is the nature of surveying and legal description writing that techniques, technology, skill and interpretation over time have resulted in multiple solutions for a given set of features. Cadastral fabrics have a derived status that must account for all the component divisions of land that led to the configuration at present. Based upon a standardized assessment of the reliability (quality, accuracy) of each element in a measurement network, an adjustment process is applied to find the best coordinate values for the points within the area of adjustment.

Adjustment is an art as well as a mathematical process. The measurement analyst has a variety of optional methods available to discover gross errors (blunders and anomalies), to narrow the adjustment area, and to report on the results of adjustment. Analysis and adjustment happen together in a series of iterations, during which edits occur, reliability is reported and revised, changes are evaluated, and new solutions are attempted.

The measurements and measured features that comprise a measurement network become the basis for higher-tiered fabrics (legal description and parcel). As adjustment alters coordinate values, the geometry of a feature changes. The NILS data model concept provides for the maintenance of topological associations between tiered fabric features and their underlying measurements. This model supports the qualitative evolution of a fabric over time in response to transactions that supply better data. As the measurement network is adjusted (perhaps to incorporate new survey data), the topologically-associated feature geometries in related fabrics would automatically update.

New Concepts

Adjustment Limits. Values that indicate when sufficient numbers of least square analysis iterations have been reached. This prevents endless looping of iterations. There are two types of limits: *residual tolerance* and *iteration limit*.

Iteration Limit. The maximum number of iterations an adjustment can have before it is assumed that the solution is diverging.

Parametric Least Squares Adjustment. A Least Square Analysis/Adjustment that considers the quality of data that varies throughout the data set. A weighted least square adjustment.

Reliability Parameter Form. A data entry tool accessible prior to successive *least square adjustment* sessions that allows the actor to set or adjust the *reliability values,* such as (1) to toggle on/off function to calculate *reliability values*, and (2) to set a buffer distance around the selected set of *measurement features* to limit the actual set of *measurement features* to be used when generating *reliability values.*

Residual Tolerance. A small distance amount (such as 0.01 feet) under which further refinement through network adjustment would not result in any meaningful positional refinement.

Reliability Values. Data describing the ellipse surrounding an adjusted point's coordinates that represent a statistical chance that the true coordinate values will be within the ellipse. Ninety five percent chance is a usable measure.

Robusting. A technique in *Least Square Analysis/Adjustment* where data discrepancies are localized to where they occur rather than the normal smoothing out over a large area. This is a technique to locate *blunders*.

Key Features and Functionality

This set of operations enables the actor to iterate through a successive series of adjustments. A range of adjustment and analysis options (e.g., anomaly detection, reliability reporting and robusting) are provided—the actor may specify the parameters and methods to apply during each iteration. The analysis is supported by tabular reports and a map view. The actor can manage the map view to symbolize various aspects of the adjustment—error ellipses, adjustment factors, reliability values, etc. Multiple solutions may be saved so that they can be reconstructed and used in future analyses or adjustments.

Application Integration

Measurement networks may be as small as a traverse (several survey points) or as large as a state. The actor controls the extent and type of adjustment.

As *anomalies* and *errors* are found, the actor would utilize the ***MM-03 Edit Measurement Data*** tools to make corrections. Input to the adjustment process may be manual (via the ***MM-03 Edit Measurement Data*** tools) or by import (e.g., from a *Field Survey*). Conversion to or from commercial survey software systems would be a useful integration function.

It is important to give the actor control in managing the means by which (geometric/topological) associations are made and handled during the update process. Actors will want to have feature-by-feature control on the update process—a continuum of actor-defined control, from locking the geometry of some related features to the automatic adjustment of others.

Development Implications

Support for the tiered, topologically-integrated data model requires an application to manage dynamic object-object relationships that is backed by a correspondingly complex database implementation.

9.4.2 MM-02 Adjust and Analyze Measurement Network Overview

Use Case	**MM-02 Adjust and Analyze Measurement Network**
Description	Perform an iterative *parametric least squares adjustment* on a *measurement network* to analyze and adjust coordinate values for points. Generate statistics on measurement and coordinate reliability. May be used in resolving the cartographic and/or coordinate representation (relationship) of non-survey *features* (map control, *legal descriptions*, digitized, scanned/vectorized) relative to surveyed *features*. May be used to resolve the representation of non-surveyed *features* without reference to surveyed *features*. NOTE: A *measurement network* may be composed of *legal descriptions* as well as *measurements*.
Actors	Surveyor, Supervisor, Parcel Editor
Pre-Condition	Necessary *measurement network* features have been input.
Post-Condition	The input *measurement network* has been adjusted and analyzed as a whole to derive a revised *measurement network* in which each *point* has been given its most appropriate coordinate value and error statistics according to the adjustment parameters chosen. *Reliability values* may have been generated for adjusted *points*.
Cross-Reference	***MM-03 Edit Measurement Data; PM-04 Readjustment of Legal Description Fabric***.

9.4.3 MM-02 Adjust and Analyze Measurement Network Primary Scenario

Actor Action	System Response
1. This use case begins when the actor launches the adjust/analyze process.	Transform *measurements* into common datum and unit type. Display available *measurement network* features symbolized to indicate status, reliability, etc.). Provide tools to select data.
3. Option to select a sub-set of *measurement network* features for adjustment.	4. Update display to show spatial extent and selected *features* (symbolized to indicate status, reliability, etc.). [selected sub-set not correct] Return to #3. Display *Analyze/Adjust Parameter Form*.
5. Input to *Analyze/Adjust Parameter Form* to define parameters and options for analysis and adjustment operations. Note: Option to activate anomaly detection options. Example methods include Closure Report, Unconstrained Adjustment, Graphic of Unadjusted data, Robusting Report, Color-code snoop values, etc. Option to set reporting and statistical parameters (e.g., level of residual to report); may set *adjustment limits* (*residual tolerance* and *iteration limit*); may just generate *reliability values* on adjusted points.	6. Perform an iterative *parametric least squares adjustment* to analyze and adjust coordinate values for *points* to determine their most appropriate location according to the adjustment parameters chosen. Generate statistics on *measurement* and coordinate reliability. Generate anomaly reports and display as appropriate. Update Display (symbolized to indicate status, reliability, adjustment factor, etc.). Display choice of Revise Adjustment Parameters, Re-Iterate, Save, Generate Reliability, Quit [*adjustment limits* not reached] Automatically repeat #5 and #6 up to a preset limit of iterations. [Revise adjustment parameters] Return to #5. [Re-Iterate] Assist actor to specify an additional number of iterations from a specified solution version (return to #5). [Edit Measurements] Change incorrect measurement values detected by *robusting* or by inspection of report. [Save] Update working version of *measurement data set.* [Generate Reliability] display *Reliability Parameter Form*, go to #7 [Quit] Exit
7. Input to *Reliability Parameter Form*. Set buffer distance, etc.	8. Generate *Reliability values* for adjusted points according to parameters chosen. Display choice to Return, Revise, Quit [Return] Go to previous task. [Revise] Go to #7. [Quit] Exit.

9.4.4 MM-02 Adjust and Analyze Measurement Network Secondary Scenarios

Name	Point of Occurrence/Overview
Adjust with *Robusting*	Step #6 – After adjustment, prompt actor to modify weighting default factors. Create alternate working version and repeat Steps 5-6 until actor ends *robusting* process.
No solution with adjustment limit	Step #6 – Report to Actor (Actor may proceed to ***MM-03 Edit Measurement Data***)

9.5 MM-03 Edit Measurement Data

9.5.1 MM-03 Edit Measurement Data Analysis

Context	To build a measurement network, some initial source data is required. *Measurement data* types include raw coordinate files, survey source IDs, error estimates, etc. This is the set of tools to manually input or edit *measurement data*, often utilized in process of automating records (e.g., a township plat or survey plat). Sometimes surveyors and editors will work directly from field notes, a survey plat or other reference to directly enter coordinate information prior to performing analysis and adjustment of a measurement network. In addition to a data input application, this is also an editor. When *blunders* and/or *errors* are discovered during the analysis/adjustment process, the actor may open an edit session and make corrections to the *measurement data*.
New Concepts	***Anomaly Correction.*** Process to edit and correct anything irregular or abnormal (*blunder, error*) in *measurement data*. ***Anomaly Detection.*** Process to identify anything irregular or abnormal (*blunder, error*) in *measurement data*. ***Blunder.*** A mistake, such as recording the wrong value or measuring to the wrong feature. See *error*. ***Error.*** The imprecision of a measurement. All measurements have error. See *blunder*. ***Measurement data.*** The raw measurement files (e.g., GMM's INRAW), control points, coordinate files, survey source IDs, error estimates, and/or survey business rules that are associated with a *measurement data set*.
Key Features and Functionality	The actor may select from a set of *measurement data* types and perform manual data entry. The actor may open an edit session for an existing *measurement data set*.
Application Integration	*Measurement data* may be edited while the actor is in between iterations of analyzing and adjusting a *measurement network*. The measurement-based data model will support data validation rules, and the edit process will provide pre-defined *error/blunder* detection and correction procedures to assist the actor in cleaning *measurement data.*
Development Implications	Requires definition in the data model of the types of *measurement data* needed to build *measurement networks*.

9.5.2 MM-03 Edit Measurement Data Overview

Use Case	**MM-03 Edit Measurement Data**
Description	Manual entry/edit of *measurement data* values. Includes types of *anomaly detection* and *anomaly correction* as part of edit validation.
Actors	Data Entry Person, Surveyor, Supervisor
Pre-Condition	Actor needs to enter/edit *measurement data* values in preparation for constructing, analyzing, adjusting, or updating a *measurement network*.
Post-Condition	Data has passed verification/validation check and has been added to or updated the destination data set.
Cross-Reference	***MM-02 Adjust and Analyze Measurement Network***

9.5.3 MM-03 Edit Measurement Data Primary Scenario

Actor Action	**System Response**
1. This use case begins when the actor launches the ***MM-03 Edit Measurement Data*** process.	2. Prompt for edit session parameter form (to specify *measurement data set* and *measurement data*).
3. Actor inputs values to set edit session parameters.	4. Provide additional forms to set data and verification/validation options. NOTE: Some *anomaly detection* is intelligent based on selected *measurement data set* and *measurement data* type. Actor may modify detection/reporting options.
5. Actor inputs values to set validation parameters.	6. Process selection. Display appropriate data entry form and prompt actor to input/edit data fields.
7. Input/edit data.	8. Process edits. Some automatic data validation occurs during this processing. Provide option to run specific data validation, return to edit, save to a target *measurement data set*, close session.
9. Select Action.	10. Process selected data validation, generate reports and update graphical display as appropriate. Repeat options as provided in #8.
11. Select action. View reports, return to edit, save, exit.	12. Process action. [save] Writes or appends data to target *measurement data set*. [not done or errors detected] Repeat #2-#9 and make corrections.
NOTE: No secondary scenarios	